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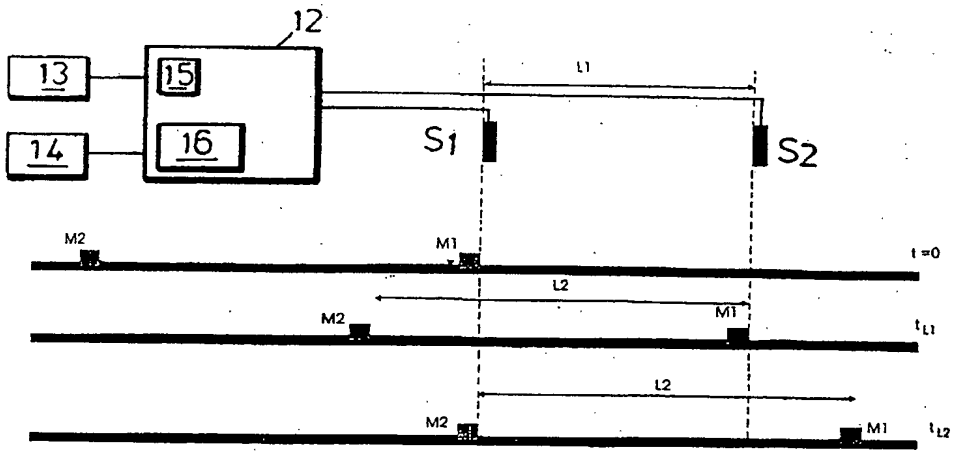
(54) Abstract Title

Chain wear measuring apparatus and method using two fixed sensors and two chain markers, and a control box with excessive chain elongation alarm

(57) A chain wear monitoring apparatus, suitable for monitoring elongation in a chain drive assembly, comprises first and second sensors S1, S2, mounted a fixed distance apart on a stationary support, and first and second markers M1 and M2 mounted, initially at a fixed and recorded distance apart, on the chain. A control unit 12 comprises a timer 15 which, triggered by electrical signals from the sensors S1, S2 generated as the chain markers M1, M2 pass the sensors S1,S2, measures the time elapsed between the signals generated for each of markers M1,M2 passing each of sensors S1, S2. From the signals generated the control unit processor 16 calculates the length of chain between the two markers M1,M2 and compares it to the original pre-measured length of the chain span which is stored a memory bank. Should any elongation in the chain exceed a pre-set threshold value, the control unit 12 sends a signal to activate an alarm, such as a visual 13 or audio 14 alarm to alert an operator of the apparatus. Also disclosed is an associated method and a kit of parts forming the apparatus. The system may incorporate magnets as the markers M1,M2 and Hall effect sensors S1,S2 or an optical / laser based system. The chain may feature further pairs of markers dividing the chain into a plurality of sections over each of which elongation may be measured separately. The control unit 12 may be configured to measure and display a variety of variables associated with chain motion, eg. velocity, average chain wear.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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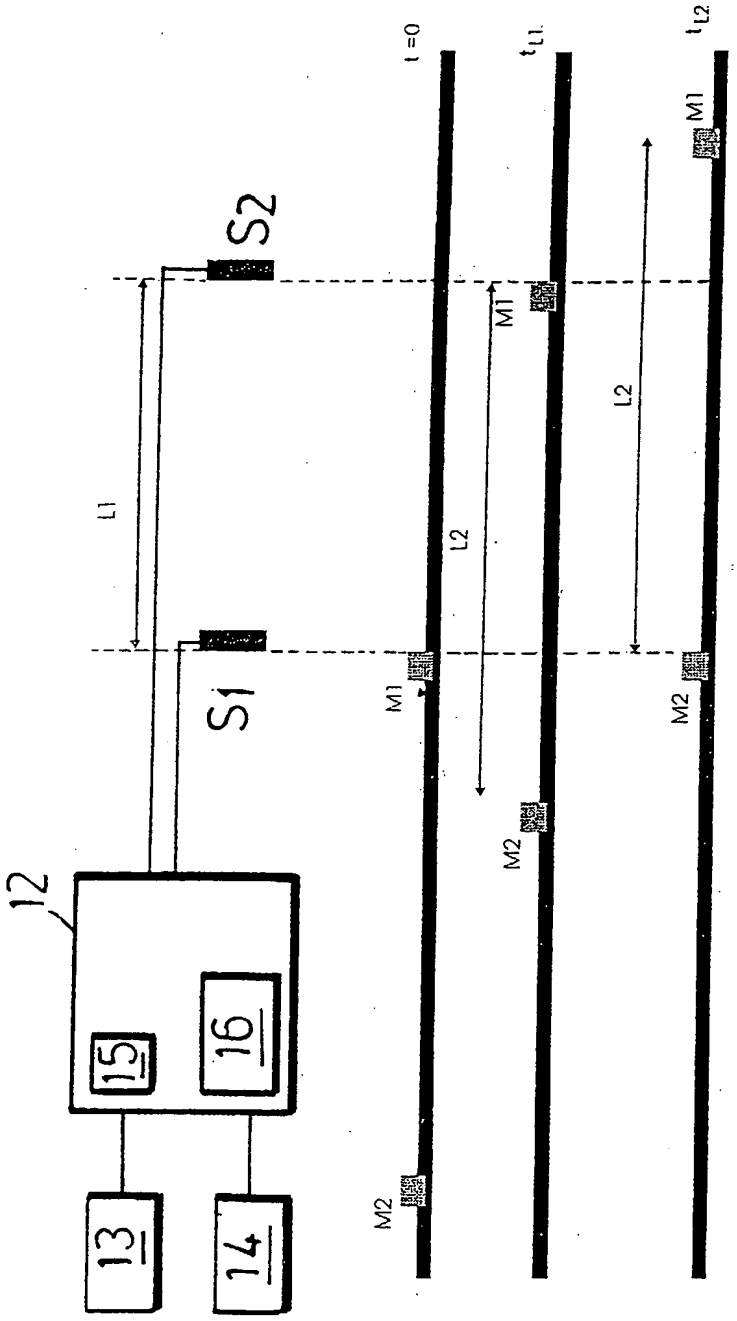

CHAIN WEAR MONITORING APPARATUS AND METHOD

The present invention relates to chain wear monitoring apparatus and an associated method.

Chain drive assemblies are used in many applications such as, for example, in conveyor systems used on manufacturing production lines, in transportation systems such as escalators, elevators or leisure rides (roller coasters etc.), and in internal combustion engines for vehicles. In many applications multiple strands of chain will be used in a single drive assembly.

A chain drive assembly typically comprises at least one endless loop chain that passes around spaced wheels one of which is driven in rotation so as to circulate the chain and any components connected thereto. A chain typically comprises a plurality of chain link assemblies that are interconnected by pins that pass through overlapping apertures in adjacent link assemblies.

Over a period of use, a chain will be subjected to wear by virtue of the rubbing friction between adjacent link assemblies and between the pins and the assemblies. This wear results in elongation of the chain and eventually the chain will have to be replaced to avoid failure of the drive assembly. The rate of wear of a chain is dependent on the nature of the drive assembly in which it is fitted and the loads to which it is subjected. Failure cannot therefore be predicted with any certainty and regular visual inspection and/or manual measurement is required. This is obviously undesirable as it is labour intensive, imprecise and requires operation of the chain drive assembly to be temporarily interrupted.

US 5,490,590 describes a chain wear monitor in which the length of a section of a chain is measured during regular operation of the chain drive system. The monitor comprises a wheel that is brought into frictional engagement with the chain. The wheel is mounted on a shaft that is connected to an encoder by a flexible coupling. The encoder translates rotational movement of the shaft into an electrical signal that is passed to a controller for processing. At the same time, the presence of each chain link is detected by a proximity sensor as it passes a predetermined location. The sensor generates a count signal that is passed to a controller for processing. The controller calculates from the distance and count signals a distance measurement per pre-

selected number of chain links. This arrangement has to be incorporated into the chain drive system and is prone to inaccuracies caused by relative slip between the friction wheel and the chain.

It is an object of the present invention to obviate or mitigate the aforesaid disadvantages and to provide for a method and apparatus for automatically monitoring the wear of a chain in-situ.

According to a first aspect of the present invention there is provided chain wear monitoring apparatus for automatically monitoring the wear of a chain when in operation in a chain drive assembly, the apparatus comprising:

first and second sensors mounted on a stationary support at a predetermined fixed distance apart and for generating electrical signals in response to the detection of at least first and second markers associated with the chain, the markers being disposed initially at a predetermined distance apart;

a control unit connected to said sensors so as to receive said signals therefrom;

the control unit comprising a timer that is triggered upon receipt of said signals from said sensors so as to measure the elapsed time between receipt of signals from the sensors;

the control unit being configured to measure a first elapsed time value between signals generated by one of the markers passing between first and second sensors and to determine the speed of travel of the chain from the first elapsed time value and the value of the predetermined distance between the sensors;

the control unit also being configured so as to measure a second elapsed time value between signals generated by the first marker passing one of said sensors and the second marker passing one of said sensors;

the control unit incorporating means for calculating the distance between the markers from the determined speed of travel of the chain and the first and second elapsed time values, means for calculating the elongation of the chain by deducting the predetermined distance between the markers from the calculated distance between the markers, and means for comparing the calculated elongation with a predetermined threshold value; and

an alarm signal generator connected to the control unit and for issuing an alarm signal if the calculated elongation exceeds said threshold value.

The invention allows the wear of a chain to be monitored automatically in real time without interruption of the operation of the chain drive assembly and without the need to remove the chain from the drive assembly. It can be used to predict or determine when a particular chain will require replacement and to assist in the diagnosis of faults in a chain drive assembly. Furthermore the apparatus can be used to determine the relative elongation and wear of different sections in a single chain.

The alarm signal may be visual or audible.

Where two or more parallel chains are used in the drive assembly the apparatus can be used to compare the wear of the chains.

Preferably the control unit comprises means for calculating the rate of wear of the chain over a period of use.

The apparatus may further comprise a visual display for displaying the calculated chain velocity, length, rate of wear and/or the presence of alarm signals.

Preferably the calculated elongation is compared with two predetermined thresholds representing different values of chain elongation and the alarm signal generator is designed to issue first and second alarm signals.

The apparatus may have two or more sets of first and second sensors for monitoring wear in two or more chains each having at least two markers. The control unit comprises means for comparing the calculated values of chain elongation and to generate a signal to trigger the alarm signal generator if the difference between the values exceeds a predetermined threshold value

Preferably the markers are designed to fit directly or indirectly to the, or each, chain.

In one preferred embodiment the distance between the sensors is equal to the initial predetermined distance between markers and therefore the second elaspsed time value is that between signals generated by the first marker passing the first sensor and the second marker passing the second sensor.

The sensors are preferably inductive or Hall-effect type, although other types may be used.

The control unit may be configured to monitor chain wear at different sections along a chain by using more than two markers, means being provided to calculate the chain elongation at each of the different sections along chain. The control unit may comprise a comparator for comparing the calculated values of chain elongation at each of the different sections along the chain and may generate a signal to trigger the alarm signal generator if one section of the chain is wearing more rapidly than another.

The control unit may also comprise means for calculating the average wear of the chain from the calculated values of chain elongation.

According to a second aspect of the present invention there is provided a method for automatically monitoring the wear of a chain when in operation in a chain drive assembly, using first and second sensors disposed at a predetermined fixed distance apart and for generating electrical signals in response to the detection of at least first and second markers associated with the chain, the markers being disposed initially at a predetermined distance apart, and using a control unit comprising a timer that is triggered upon receipt one of said signals from one of the sensors so as to measure the elapsed time between receipt of signals from the sensors; the method comprising the steps of :

measuring a first elapsed time value between signals generated by one of the markers passing between first and second sensors;

determining the speed of travel of the chain from the first elapsed time value and the value of the predetermined distance between the sensors;

measuring a second elapsed time value between signals generated by the first marker passing one of said sensors and the second marker passing one of the sensors;

calculating the distance between the markers from the speed of travel and the first and second elapsed time values;

calculating the elongation of the chain by deducting the predetermined distance between the markers from the calculated distance between the markers;

comparing the calculated elongation with a predetermined threshold value; and

generating an alarm signal if the calculated elongation exceeds said threshold value.

According to a third aspect of the present invention there is provided a kit of parts for automatically monitoring the wear of a chain when in operation in a chain drive assembly, the apparatus comprising:

first and second markers for connection directly or indirectly to the chain;

first and second sensors mounted on a stationary support at a predetermined fixed distance apart and for generating electrical signals in response to the detection of said first and second markers, the markers, in use, being disposed initially at a predetermined distance apart;

a control unit connected to said sensors so as to receive said signals therefrom;

the control unit comprising a timer that is triggered upon receipt of said signals from said sensors so as to measure the elapsed time between receipt of signals from the sensors;

the control unit being configured to measure a first elapsed time value between signals generated by one of the markers passing between first and second sensors and to determine the speed of travel of the chain from the elapsed time value and the value of the predetermined distance between the sensors;

the control unit also being configured so as to measure a second elapsed time value between signals generated by the first marker passing one of said sensors and the second marker passing one of the sensors;

the control unit incorporating means for calculating the distance between the markers from the determined speed of travel of the chain and the first and second elapsed time values, means for calculating the elongation of the chain by deducting the predetermined distance between the markers from the calculated distance between the markers, and means for comparing the calculated elongation with a predetermined threshold value; and

an alarm signal generator for issuing an alarm signal if the calculated elongation exceeds said threshold value.

A specific embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

figure 1 is a schematic representation of the chain wear monitoring apparatus and the chain of a chain drive assembly shown at three different points in time during its travel.

The exemplary chain wear monitoring apparatus comprises a pair of inductive or Hall-effect sensors S_1, S_2 disposed near to the chain 10 at a fixed distance L_1 apart on a stationary support structure 11 such as, for example, a framework that carries the chain drive assembly. The sensors S_1, S_2 are connected to a control unit 12 that receives and processes the signals from the sensors S_1, S_2 and generates output signals that drive a visual display 13 and an alarm unit 14.

The control unit 12 comprises conventional signal conditioning circuitry, a timer 15, a processor 16 with associated memory, and an output circuit for driving the visual display or alarm unit

The chain 10 of the chain drive assembly is in the form of an endless loop that passes around at least a pair of wheels (not shown), one of which drives the chain. A section of the chain 10 is represented in figure 1 and is shown as travelling in the direction from left to right.

The chain 10 is fitted with two markers M_1, M_2 that are composed of a material to which the sensors are sensitive (e.g. magnetic elements) and are disposed initially at a predetermined distance apart L_2. The markers M_1, M_2 may simply clip or otherwise fasten directly or indirectly on to the chain.

Before operation of the chain wear monitor the control unit 12 is pre-programmed with the values of distance L_1, the initial distance L_2 between the markers, a first threshold wear length L_{a} and an ultimate threshold wear length L_{u}, all the values being stored in the processor memory.

When the chain drive assembly is in operation the chain circulates around the wheels and passes the sensors S_1, S_2 from left to right in the view shown in figure 1. As each marker M_1, M_2 passes in front of a sensor an electrical signal is generated and passed to the control unit 12.

As marker M_1 passes sensor S_1 the control unit 12 starts the timer 15 in response to the signal received. This is represented in figure 1 by the diagram labelled as t=0. When marker M_1 then passes sensor S_2 the time elapsed in travelling the

distance L_1 is recorded as t_{L1} . Shortly after marker M_2 passes sensor S_1 and the time elapsed in travelling the distance L_2 is recorded as t_{L2}.

The elongation of the chain is then calculated from the recorded elapsed time values t_{L1} and t_{L2} and the pre-programmed values of L_1 and L_2. The elongation of the chain is calculated as:

$$L_w = (L_1 \, . t_{L2}/t_{L1}) - L_2$$

Where L_1/t_{L1} is the velocity of the chain and is recorded separately by the control unit for information purposes.

The processor 16 continually compares the present calculated elongation L_w of the chain with the first wear length threshold L_a and when it exceeds the threshold a signal is generated to sound a first alarm signal. Similarly, a comparison is made with the ultimate wear length threshold L_u and when it is exceeded the control unit will generate a second signal to sound a second alarm.

The display continually provides a reading of the current chain velocity, current chain elongation length L_w and the rate of elongation (rate of wear).

The apparatus can be used to monitor the wear of two chains that are running in parallel to drive a conveyor such as, for example, an escalator. In such an application each chain has at least two markers and a pair of sensors mounted in proximity thereto. The control unit receives signals from both sensors and is pre-programmed with the parameters relating to each chain. The chain wear is monitored in both chains by the control unit. The difference between the two calculated elongation values is determined and compared to a predetermined threshold value L_d. If this value is exceeded the control unit issues a signal to the alarm signal generator and an appropriate alarm is sounded. This is particularly important in conveyors such as escalators as inequality of wear of the two chains may result in damage to the chain drive assembly or the escalator itself.

The initial distance between the markers L_2 may be set at a value greater than, less than or equal to the distance between the sensors L_1. If the distances L_1 and L_2 are arranged to be equal when the chain is new, the sensors S_1, S_2 will initially generate signals simultaneously and as the chain wears the signal generated by the passage of

the second marker M_2 past the first sensor S_1 will lag that generated by the first M_1 marker passing the second sensor S_2.

It will be appreciated that numerous modifications to the above described design may be made without departing from the scope of the invention as defined in the appended claims. For example, the chain may be fitted with more than two markers and the chain elongation measured for different sections of the chain. An average chain wear may be calculated by the control unit from the measured values. Moreover, if a comparison is made of the calculated elongation values this method enables identification of a section of chain that is wearing at a greater rate than other sections. Furthermore, the sensors may be of any suitable type for detecting the presence of a marker e.g. optical or laser based.

CLAIMS

1. Chain wear monitoring apparatus for automatically monitoring the wear of a chain when in operation in a chain drive assembly, the apparatus comprising: first and second sensors mounted on a stationary support at a predetermined fixed distance apart and for generating electrical signals in response to the detection of at least first and second markers associated with the chain, the markers being disposed initially at a predetermined distance apart; a control unit connected to said sensors so as to receive said signals therefrom; the control unit comprising a timer that is triggered upon receipt of said signals from said sensors so as to measure the elapsed time between receipt of signals from the sensors; the control unit being configured to measure a first elapsed time value between signals generated by one of the markers passing between first and second sensors and to determine the speed of travel of the chain from the first elapsed time value and the value of the predetermined distance between the sensors; the control unit also being configured so as to measure a second elapsed time value between signals generated by the first marker passing one of said sensors and the second marker passing one of the sensors; the control unit incorporating means for calculating the distance between the markers from the determined speed of travel of the chain and the first and second elapsed time values, means for calculating the elongation of the chain by deducting the predetermined distance between the markers from the calculated distance between the markers, and means for comparing the calculated elongation with a predetermined threshold value; and an alarm signal generator connected to the control unit and for issuing an alarm signal if the calculated elongation exceeds said threshold value.

2. Chain wear monitoring apparatus according to claim 1, wherein the alarm signal is visual and/or audible.

3. Chain wear monitoring apparatus according to claim 1 or 2, wherein two or more parallel chains are used in the drive assembly, the means for calculating the

elongation of the chains is configured to perform said calculation for each chain and the control unit comprises a comparator for comparing the elongation of each chain over time.

4. Chain wear monitoring apparatus according to claim 1, 2 or 3, wherein the control unit comprises means for calculating the rate of wear of the chain (or chains) over a period of use.

5. Chain wear monitoring apparatus according to any preceding claim, further comprising a visual display connected to the control unit and for displaying the calculated chain velocity, length, rate of wear and or the presence of alarm signals.

6. Chain wear monitoring apparatus according to any preceding claim, wherein means for comparing the calculated elongation compares the calculated value with two predetermined thresholds representing different values of chain elongation and the alarm signal generator is designed to issue first and second alarm signals.

7. Chain wear monitoring apparatus according to any preceding claim, further comprising two or more sets of first and second sensors for monitoring wear in two or more chains each having at least two markers.

8. Chain wear monitoring apparatus according to claim 7, wherein the control unit comprises means for comparing the calculated values of chain elongation for each chain and means to generate a signal to trigger the alarm signal generator if the difference between the chain elongation values exceeds a predetermined threshold value.

9. Chain wear monitoring apparatus according to any preceding claim, wherein the distance between the sensors is equal to the initial predetermined distance between markers and the second elapsed time value is between signals generated by the

first marker passing said first sensor and by the second marker passing the second sensor.

10. Chain wear monitoring apparatus according to any preceding claim, wherein the sensors are inductive or Hall-effect type.

11. Chain wear monitoring apparatus according to any preceding claim, wherein the control unit is configured to monitor chain wear at different sections along a chain by using more than two markers, means being provided to calculate the chain elongation at each of the different sections along the chain.

12. Chain wear monitoring apparatus according to claim 11, wherein the control unit comprises a comparator for comparing the calculated values of chain elongation at each of the different sections along the chain and means for generating a signal to trigger the alarm signal generator if one section of the chain is wearing more rapidly than another.

13. Chain wear monitoring apparatus according to claim 11 or 12, wherein the control unit comprises means for calculating the average wear of the chain from the calculated values of chain elongation.

14. A method for automatically monitoring the wear of a chain when in operation in a chain drive assembly, using first and second sensors disposed at a predetermined fixed distance apart and for generating electrical signals in response to the detection of at least first and second markers associated with the chain, the markers being disposed initially at a predetermined distance apart, and using a control unit comprising a timer that is triggered upon receipt one of said signals from one of the sensors so as to measure the elapsed time between receipt of signals from the sensors; the method comprising the steps of: measuring a first elapsed time value between signals generated by one of the markers passing between first and second sensors; determining the speed of travel of the chain

from the first elapsed time value and the value of the predetermined distance between the sensors; measuring a second elapsed time value between signals generated by the first marker passing one of said sensors and the second marker passing one of said sensors; calculating the distance between the markers from the speed of travel and the first and second elapsed time values; calculating the elongation of the chain by deducting the predetermined distance between the markers from the calculated distance between the markers; comparing the calculated elongation with a predetermined threshold value; and generating an alarm signal if the calculated elongation exceeds said threshold value.

15. A method according to claim 14, wherein two or more parallel chains are used in the drive assembly, further comprising the steps of calculating the elongation of each of the chains and comparing the elongation of each chain over time.

16. A method according to claim 14 or 15, further comprising the step of calculating the rate of wear of the chain (or chains) over a period of use.

17. A method according to any one of claims 14 to 16, further comprising the step of displaying the calculated chain velocity, length, rate of wear and/or the presence of alarm signals.

18. A method according to any one of claims 14 to 17, further comprising the step of comparing the calculated elongation value with two predetermined thresholds representing different values of chain elongation and issuing first and/or second alarm signals if the respective chain elongation values are exceeded.

19. A method according to any one of claim 14 to 18, wherein two or more sets of first and second sensors are used to monitor wear in two or more chains, each of the chains having at least two markers.

20. A method according to claim 19, further comprising the steps of comparing the calculated values of chain elongation for each chain and generating a signal to trigger an alarm signal if the difference between the values exceeds a predetermined threshold value.

21. A method according any one of claims 14 to 20, further comprising the step of monitoring the chain wear at different sections along a chain by using more than two markers, and calculating the chain elongation at each of the different sections along the chain.

22. A method according to claim 21, further comprising the step of comparing the calculated values of chain elongation at each of the different sections along the chain and issuing an alarm signal if one section of the chain is wearing more rapidly than another.

23. A method according to claim 21 or 22, further comprising the step of calculating the average wear of the chain from the calculated values of chain elongation.

24. A kit of parts for automatically monitoring the wear of a chain when in operation in a chain drive assembly, the apparatus comprising: first and second markers for connection directly or indirectly to the chain; first and second sensors mounted on a stationary support at a predetermined fixed distance apart and for generating electrical signals in response to the detection of said first and second markers, the markers, in use, being disposed initially at a predetermined distance apart; a control unit connected to said sensors so as to receive said signals therefrom; the control unit comprising a timer that is triggered upon receipt of said signals from said sensors so as to measure the elapsed time between receipt of signals from the sensors; the control unit being configured to measure a first elapsed time value between signals generated by one of the markers passing between first and second sensors and to determine the speed of travel of the chain from the first elapsed time value and the value of the predetermined distance between the sensors; the

control unit also being configured so as to measure a second elapsed time value between signals generated by the first marker passing one of said sensors and the second marker passing one of said sensors; the control unit incorporating means for calculating the distance between the markers from the determined speed of travel of the chain and the first and second elapsed time values, means for calculating the elongation of the chain by deducting the predetermined distance between the markers from the calculated distance between the markers, and means for comparing the calculated elongation with a predetermined threshold value; and an alarm signal generator for issuing an alarm signal if the calculated elongation exceeds said threshold value.

25. Chain wear monitoring apparatus substantially as hereinbefore described with reference to the accompanying drawings.

26. A method for automatically monitoring the wear of a chain substantially as hereinbefore described with reference to the accompanying drawings.